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[56] Citations:

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The following statements were taken from the documents submitted by the applicant

Petition for examination requested according to § 44 of the Patent Act

54 Light-Emitting Diode and Processes for their Production

57 The invention concerns a light-emitting diode and a process for its production. The light-emitting diode has an LED chip which is cast into a housing and a lens for the bundling of the rays which emerge from the LED chip.
To bundle the rays emerging from the LED chip, an area is provided between the LED chip and a casting compound forming the housing, having a refractive index (n_L) which is smaller than the refractive index (n_G) of the casting compound.

Description

The invention concerns a light-emitting diode according to the preamble of claim 1. The invention further concerns a process for their production.

Light-emitting diodes conventionally consist of a semiconductor chip enclosed by a casting compound. The semiconductor chip has a pn or np junction, and an emission of light is created in the transition region when applying a voltage.

For some applications, for example, the introduction of light into a light wave guide[1] it is necessary to bundle the radiation emitted by the light-emitting diode. For that it is known to arrange a separate lens into the optical path following the light-emitting diode.

It is furthermore known to produce a housing shape, for example, through injection molding, the outer surface of which approximates the shape of a lens. However, the application of such injection molding processes is not always possible because the bond wires which supply the semiconductor substrate with current may snap during the injection molding process. But such lens shapes may not me formed easily by a simple casting. With the lenses formed by the light-emitting diode housings there is furthermore the problem that they lie relatively distant from the emitting surface, so that a large portion of the emitted light does not lie in the focal point of the lens. Through that one may not achieve the desired focusing.

With respect to the extended field of the invention, reference is made to DE 43 42 840 A, US 5,229,835, EP 0 392 741 A1 and US 4,4,797,179.

It is the object of the present invention to develop a light-emitting diode such that a good bundling of the radiation emitted by an LED chip is achieved in a simple and cost-effective way.

The means for attaining this object are in the characteristics named in claim 1 as far as the device is concerned and in the characteristics named in the claims 5, 6 and 8 where the process is concerned.

A central idea of the present invention consists in that an area is provided between the LED chip and a casting compound forming the housing in which the refractive index is smaller than the refractive index of the casting compound. When passing through the

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[1] or *optical fiber, fiber optic cable*

interface between the area with a small refractive index and the casting compound a deviation occurs towards the perpendicular bisector of each surface. With a suitable design of the interface, in particular a convex interface, a bundling of the rays emitted by the LED chip takes place altogether. The bundling of the rays is thereby dependent not only on the design of the interface, but also on the ratio between the refractive indices n1 and n~. If a certain bundling is to be achieved for an application, then for the existence of certain refractive indices one must select a surface design to be determine each time. Since the optical element formed in the area mentioned lies against the emitting surface of the LED chip, the predominant part of the emitted light comes from the focal point of the lens, so that a good focusing is ensured.

Especially air or vacuum are present in the area with a small refractive index. Any other material which has a suitable refractive index may be used as an alternative.

The area with the small refractive index may be shaped in varied ways. It is, for example, possible to provide during casting a locally higher surface tension around an LED chip, so that a bubble filled, for example, with air, forms in the chip area during the casting process.

As an alternative one may arrange a placeholder medium or material in the area of the LED chip where a smaller refractive index is intended, so that the casting compound does not enter this area during the casting process. The placeholder material or the placeholder medium can be removed again following the curing of the casting compound. This is possible, for example, in that an opening is formed through the casting compound down to the area with the smaller refractive index and the placeholder medium is then suctioned out, rinsed out, etched out, etc. It is also possible to apply material [in a] structured [way], similarly to a "rapid-prototyping" process. As an alternative one can also arrange at first a material with a smaller refractive index around an LED chip, so as to apply in the next step the casting compound forming the housing. With this, too, one creates a transition from a smaller refractive index to a larger refractive index, so that a light-collecting optical device is essentially formed.

If the above mentioned area is filled with air, then a simultaneous or later formation of a connection between this area and the external environment is of advantage, as the

LED chip can be cooled by it. Since the fiber core of a light wave guide, for example, of PMMA withstands only 85°C, the light-emitting diode should not become much warmer.

A simple example of embodiment of a device according to the invention is explained more closely with reference to the attached drawings.

The drawings show in

Fig. 1 a schematic representation of a light-emitting diode according to the invention, and

Fig. 2 a schematic representation of a magnified section from **Fig. 1**.

An LED chip **10** is provided in **Fig. 1**, which consists of a pn junction, where light is emitted in the junction area when applying a voltage. Arranged on the LED chip **10** there is a bond pad **19**, fastened to which there is a bond wire **18**, which on the other hand is lead to a lead frame **16**, where it is again fastened to a bond pad **19**. The LED chip **10** is furthermore arranged on a substrate **14**.

The overall arrangement is integrally cast into a transparent material with a certain refractive index n_G (casting compound **13**) which forms the housing of the light-emitting diode. The connection pins projecting from the lead frame are not represented here.

Kept free between the LED chip **10** and the casting compound **13** there is an approximately semispherical area **12** in which there is air. This area can be fashioned in a form that achieves the desired bundling or scattering effect. The interface with the casting compound in particular is designed so that a ray-bundling effect is achieved, as is still to be explained in the following.

As material in the area **12** one may use any material which has a refractive index n_L smaller than the casting compound. As an alternative one may naturally use also vacuum in the area **12**.

The effect of the bubble formed in the area **12** is represented in **Fig. 2**. Diverging rays consequently emerge from an area of the LED chip **10**, which are each incident at an angle $\alpha 1$, $\alpha 2$ and $\alpha 3$ with respect to the bisector perpendicular to the surface of the casting compound **13**. A refraction towards the perpendicular bisector occurs due to the refractive index ratio $n_L:n_G$, so that all angles $\beta 1$, $\beta 2$, $\beta 3$ are each smaller than the corresponding incident angle $\alpha 1$ to $\alpha 3$. The bundle of rays emerging from the LED chip **10** is thus bundled, so that the output cone becomes narrower.

This type of light-emitting diode is suitable everywhere where a special bundling is necessary. They may be used, for example, for a better coupling into optical wave guides.

Patent Claims

1. Light-emitting diode with an LED chip, which is integrally cast into a housing, and with a lens for the bundling of the rays emitted from the LED chip, **characterized in** that an area (**12**) is provided between the LED chip (**10**) and a casting compound (**13**) forming the housing, having a refractive index (n_L) which is smaller than the refractive index (n_G) of the casting compound.

2. Light-emitting diode according to claim 1, characterized in that the transition surface between the area (**12**) and the casting compound (**13**) is convex shaped.

3. Light-emitting diode according to claim 1 or 2, characterized in that air or vacuum is provided in the area (**12**).

4. Light-emitting diode according to claim 3, characterized in that in case of a filling of the area (**12**) with air, the area (**12**) is connected with the ambient air.

5. Process for the production of a light-emitting diode according to one of the claims 1 through 4, characterized in that a locally higher surface tension is created with the casting compound (**13**) around an LED chip (**10**) during the casting of the housing.

6. Process for the production of a light-emitting diode according to one of the claims 1 through 4,
characterized in
that at first a placeholder medium is arranged in the area (**12**) around an LED chip (**10**),
that the LED chip (**10**) together with the placeholder medium is integrally cast into a casting compound (**13**), and
that the placeholder medium is removed again.

7. Process according to claim 5 or 6, characterized in that, during the production of the light-emitting diode or afterwards, a connection is created which connects the area (**12**) with the external environment.

8. Process for the production of a light-emitting diode according to one of the claims 1 through 5,
characterized in

that a medium with a refractive index (n_L) smaller than the refractive index (n_G) of the casting compound (**13**) is arranged in an area (**12**) around an LED chip (**10**)

and

that the LED chip (**10**) together with the medium are integrally cast into the casting compound (**13**).

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